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Straight sowing — no-till: agrophysical expertise of the stage of transition.

Bulyhin S.[1], **Vitvitskyi S.**[2], **Antoniuk D.**[3]

National university of bioresources and natural management of Ukraine, Heroiv Oborony Str., 15, Kyiv, 03041, Ukraine; e-mail: [1–3]*s.bulygin@ukr.net*

The purpose. To carry out agrophysical expertise of typical superdeep low humus sandy loam chernozem of Left-bank Forest-steppe of Ukraine according to indexes of structurally-modular and humus state during the period of transition from straight sowing to no-till system. **Methods.** General scientific (field, morphological-genetic, comparative-analytical, agro-analytical, laboratory) and special (determination of the content of elementary soil particles and micro aggregation by S. Bulygin microscopy method). **Results.** It is experimentally fixed that 10-years application of straight sowing does not cause as a whole essential changes in macro structural nature of soil in comparison with moldboard plowing. However, its fertilized backgrounds increase lumpiness (index of deflationary resistance) and average diameter of water-resistant compounds (index of water-erosion resistance). Thus aggravation of micro aggregation state of soil, caused by absence of protective 3 – 4-cm layer of plant residues which are the precise attribute of no-till system is registered. **Conclusions.** Ten years' application of straight sowing of crops on typical sandy loam chernozem leads to its deep-seated agrophysical degradation because of decrease micro-aggregation of soils and does not promote essential increase of productivity of crops. The transition period from straight sowing to no-till system should be as much as possible short (not more than 4 years). No-till system begins from the moment of formation of 3-4-cm layer of mulch on the surface of soil under condition of its 100% coatings.

Key words: *macrostructure, elementary soil particles (ESP), quotient of* micro-aggregation*, technological normative of power load.*

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The transition to the No-till system is not just a change in the tillage system; it is, in fact, a new system of agriculture [10]. The world's No-till area exceeds 100 million hectares, and is growing fast. In Ukraine there are no accurate data available. Both positive and negative aspects of no-till have been discovered. The advantages include energy saving, a significant reduction in labor costs, a sharp decrease in technological impact on soil, reliable anti-deflation protection, and a significant reduction of erosion hazard. Yet, zero-till has obvious negative aspects, which are manifested in the tendency to increase the structural density, hardness and some other indicators of soil strength, a decrease in moisture conductivity, an increase in weediness and morbidity (especially in the first 3-4 years), and a significant increase in the costs of machinery and chemical crop and soil protection agents. In Ukraine, due to agricultural holdings, another very negative trend is emerging, when the zero-till technology of growing so-called 'market' agricultural crops leads to the destruction of commercial livestock breeding. This is caused, on the one hand, by the pursuit of profits using a minimum of workers, which leads to the deterioration of villages, and, on the other hand, by the fact that zero-till is difficult to combine with fodder crops – the basis of livestock breeding.

This is an urgent problem, which, although it is beyond the scope of the current article, needs to be urgently resolved, because the sale of raw materials in the form of grain depletes the soil and feeds the "golden" billion, leading to the impoverishment of Ukrainian agrarians.

A paradoxical situation has arisen, when not only agricultural holdings but also farmers are widely applying No-till without a solid scientific support. Unfortunately, the NAAS has not created a system of scientific testing grounds for this new farming system. In our opinion, there is a complete disregard for the concepts of "no-till" and "zero-till". It is believed that as soon as the soil has ceased to be cultivated, then No-till takes place. Yet, "zero-till" technology of growing crops can only be confirmed when the surface of soil has a 3-4 cm layer of plant residues at 100% coverage [2,3]. Until then, one can talk about the so-called transition period.

The aim of research: To conduct an agro-physical expert review of the soil during the transition to No-till.

The object and methods of research

The research was conducted as a stationary field experiment in 2018 at the Panfilska Research Station of the RC "Institute of Agriculture of the NAAS", which is located in the Yahotyn district of the Kyiv region. The soil – chernozem is a typical super-light loam, the morphological profile of which is presented in Fig. 1. It must be said that this is not just a soil – it is a miracle of nature. The genetic profile is up to 2 meters, on the whole depth, that is, up to 2 meters the density (volumetric mass) does not exceed 1.22 g / cm3, with carbonates almost on the surface. This soil is naturally designed for no-till, i.e., the miracle situation where you only plant and harvest. First, it is one of the best soils in the world, and secondly, in the list of soils of Ukraine it is the first among those recommended for No-till.

In 2008, in the above location, researchers started a stationary experiment to study the "zero-tillage" technology. Therefore, they observed a complete 10-year period of no-till, which gives some data for determining the changes in the state of the soil compared to the traditional moldboard plowing cultivation system. Crops were grown with 4-way crop rotation: winter wheat - sunflower - barley - soybean. That was the combination of so-called market crops, which is typical nowadays, without taking into account the currently non-existent livestock breeding. The current situation is as follows: an average manufacturer has a load of more than 1000 hectares, the crops are harvested and shipped out, and the countryside is without land and life. Fig. 2 shows the projective cover of nutrient residues on the surface of the soil.

Figure 1

Morphological profile of typical light loam chernozem

Soil structure and profile

Hk $\frac{0-63}{63}$ **cm;** humus, in the upper half: fresh, dark grey, light-loam; lumpy-powdery-granular, loose, thin; carbonates flow from a depth of 10 cm; worm holes, coprolites of earthworms, mole passages are filled with parent rock; roots are vertically located, scarce and thin; in the lower half: fresh, dark grey, light-loam, lumpy-grained, lightly packed, finely porous, carbonate, worm holes, coprolites of earthworms, mole passages are filled with parent rock; roots are vertically located, scarce and thin; the transition is gradual, along the even line;

Npk $\frac{63-90}{27}$ **cm;** upper transitional; fresh; yellowish-gray, upper part more humus, medium loamy; lumpy; loose; thin; carbonaceous; a lot of worm holes, mole passages are filled with the surface soil; the transition is noticeable; the line is even;

PHк $\frac{90-142}{52}$ **cm;** lower transitional; fresh; variegated, dirty yellow, weakly and unevenly humus, moderately loamy, loosely lumpy; loose; porous; a lot of carbonates in the worm holes, the bottom contains a lot of mole passages; the transition is noticeable; the line is even;

P(h)k $\frac{142-199}{57}$ **cm;** loess with mole passages, yellowish-brown; humid; medium loamy; lumpy; loose; porous; mole passages and worm holes contain a lot of carbonates (mold, tubules); strongly interrupted by shrews, the transition is noticeable, the line is wavy;

Pk, 199 cm and below: carbonate loess, pale, coarse silt, light-loamy with copious carbonate mold.

Soil name: Chernozem, typical low-humus light loam with loess base.

In Fig. 2 it is clearly seen that the projective cover reaches a maximum of 80% with a single-straw layer of winter wheat. In addition to sunflower seedlings, no remaining stover of other crops is visible. It cannot exist in the conditions of the above 4-crop rotation. Except for winter wheat, nutritious fragments of other crops remain only until the summer of the next year. In such a crop rotation, the transition period will be permanent, as the norms of surface cover of the soil, which are characteristic of No-till, will never be achieved.

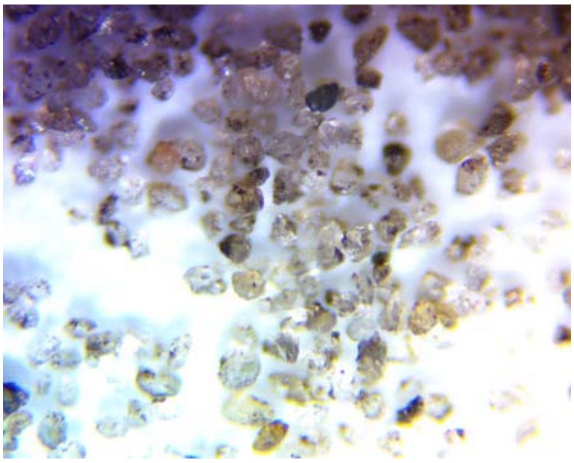
Figure 2.

Projective cover of the soil surface after 10 years of no-till

Methods of determining the parameters of the structural aggregate state and soil humus were conventional [1,11], the content of elementary soil particles (ESP) and microaggregation were determined by the microscopic method (Fig. 3) designed by Bulygin [4,5,7].

Figure 3

Microscopic field of 0.05 mm soil fraction



Results and discussion

Parameters of the macrostructure of typical light-loam chernozem for different cultivating systems are shown in Table 1. Comparison of fertilized variants (fertilizer standards for crops are shown in Table 5) indicates a significant improvement in crumbling (deflation resistance index) [1] and the weighted average diameter of water-resistant aggregates (soil erosion parameter) [1] for No-till. These parameters are medium-dynamic and easily change by literally one operation of soil cultivation. Lightweight loamy chernozems are not resistant to mechanical influences and other technological energy. Therefore, it is not surprising that this has happened. That is, the replacement of traditional cultivation with no-till dramatically reduces the erosion and deflation danger. This is especially true in the context of the so-called technological erosion [9]. When our soil is cultivated, there is a terrible dust cloud. In the spring of 2018, the authors saw this disaster personally when the soil was cultivated using a rotary plow, which is an environmental crime. If you imagine that the whole field is cultivated at the same time, this would cause a major dust storm. Then even the most serious ecological gangster would realize it was a crime. Rotary plows and chernozems are not compatible; this tool can only be used to even out sand on the beaches, yet it means death for the field.

Table 1. Macrostructure of typical light-loam chernozem, stationary research of the Panfilska Research Station “NSC Institute of Agriculture of NAAS”*

Cultivation type	Layer, cm	C str.*	> 0,25 mm, %	S, %	> 0,25 water-proof, %	Average weighted d, mm
No-till,NPK	0-10	3,0	80,7;	59,1	61,6	0,55
	20	2,5	83,7	63,2	65,6	0,69
	30	3,0	86,3	63,8	65,6	0,42
	40	2,9	86,8	61,5	57,1	0,73
Moldboard plowing, NPK	0-10	3,7	86,2	46,7	61,3	0,34
	20	2,3	79,7	55,8	59,6	0,32
	30	4,0	87,3	57,2	73,7	0,46
	40	3,3	85,7	59,1	68,4	0,41
Control	0-10	5,0	90,7	47,2	73,3	0,57
	20	7,8	97,8	67,5	78,7	0,60
	30	4,9	96,8	77,1	73,4	0,60
	40	6,3	95,8	75,4	81,0	0,80
HIP 0.95	0-10	0.4	5,1	3,2	5,1	0,10
	20	0,7	4,9	3,1	4,2	0,10
	30	0,6	5,1	2,9	4,9	0,07
	40	0,8	6,1	3,3	5,3	0,06

* Cstr.- coefficient of structure by Revut; > 0,25 mm,% - the sum of aggregates larger than 0,25 mm; S,% - lumpiness (sum of aggregates larger than 1 mm); > 0,25 Waterproof,% - the sum of water-proof aggregates larger than 0,25 mm; Average weighted d – the average weighted diameter of water-resistant aggregates.

But even on the basis of Table 1 it can be said that no fundamental changes have occurred in the macrostructure after the transition to No-till. In fact, the indicator “the sum of water-proof aggregates larger than 0,25 mm” is more inert, and only its change can be the sign of a genetically determined change in the water resistance of macro aggregates. In control area (plowing without fertilizers), there were no significant changes in the parameters of the macrostructure in comparison with No-till (in Table 1, variant No-till, as defined in the outline of stationary field experiment). The energy of fertilizers, however, has a negative effect on the above, as will be discussed below. Table 2 shows the results of microscopic estimation of Elementary Soil Particles (ESP) and the calculated Ca – coefficient of microaggregation.

Table 2. Microaggregation of typical light loamy chernozem for various cultivation technologies in 4-crop rotation

No.	Variant	Depth, cm	ESP content,%	C_a*
1	No-till with fertilizers	0 - 10	5,95	0,69
2	Same as above	10 - 20	1,90	0,88
3	Same as above	20 - 30	2,60	0,80
4	Same as above	30 - 40	2,60	0,90
5	Plowing with fertilizers	0 - 10	2,50	0,82
6	Same as above	10 - 20	2,61	0,87
7	Same as above	20 - 30	1,66	0,87
8	Same as above	30 - 40	1,55	0,92
9	Plowing without fertilizers	0 - 10	0,72	0,92
10	Same as above	10 - 20	0,29	0,89
11	Same as above	20 - 30	0,26	0,91
12	Same as above	30 - 40	0,58	0,86
$HIP_{0.95}$			0,83	0,11

* Coefficient of aggregation by Baver and Rhoades

We will begin analysis of the data in Table 2 by emphasizing that the ESP indicator has the highest dynamics among all agro-physical parameters of soils, while the C_a is the most inert indicator, which is determined by the granulometric composition, quantity and quality of humus [7]. We observe a significant deterioration of microaggregation parameters after 10 years of no-till.

The ESP indicator is the equivalent of the soil system's entropy; the higher it is, the more "noise" exists in the system, which, in the long-term, leads to a transition to a lower level of its organization and stability. Already, there is a result, i.e., a significant reduction of C_a for zero-till variant (No-till in the experiment outline). This is already a problem – the 10-year maintenance of the soil on the surface without a reliable protection by a layer of plant residue leads to deep degradation in microaggregation, which is not yet traced at the level of macro-aggregation. Moreover, indicators of the total humus content have not changed significantly (Table 3).

Table 3. The content of total humus in typical light loam chernozem

No.	Variant	Depth, cm	Humus content,%
1	No-till with fertilizers	0 - 10	3,23
2	Same as above	10 - 20	2,80
3	Same as above	20 - 30	2,90
4	Same as above	30 - 40	2,46

5	Plowing with fertilizers	0 - 10	3,24
6	Same as above	10 - 20	3,34
7	Same as above	20 - 30	3,10
8	Same as above	30 - 40	2,85
9	Plowing without fertilizers	0 - 10	3,21
10	Same as above	10 - 20	3,31
11	Same as above	20 - 30	2,90
12	Same as above	30 - 40	2,90
$HIP_{0,95}$			0,4

We have recorded, at midday in summer, the heating of the open surface of chernozem (black fallow) to72°C. And here an uncovered surface has been "heated", without change, for 10 years. In addition, there is the commonly known destructive effect of cycles on the soil: freezing-melting, wetting-drying, dispersive effect of the running machine parts during sowing, spraying and harvesting. The result is as expected – the quality (aggregation ability) of humus has decreased, which caused a significant drop in C_a. We can say that this is a sentence to long-term zero tillage. During the plowing, the upper layers of the soil are turned upside down to "rest", while here the 0-10 cm layer is in tough, destructive conditions without any rest.

Clearly, the period of the so-called zero-tillage should be as short as possible; during this period, a reliable protector against destruction should be formed, i.e., a powerful (3-4 cm) layer of plant residues. This requires the appropriate crop rotation. The rotation that we have studied is fundamentally unsuitable – out of the 4 crops, only the winter wheat produces a significant amount of nutrient remains. There is no need to invent something new; the Americans, who are the founders of No-till, have clearly shown that without corn it will be difficult to produce a sufficient layer of plant residues. In our view, the following chain of three-crop rotation is acceptable: winter wheat (green manure must be sowed after wheat harvesting or, better still, simultaneously with harvesting, by filling the reaper with seeds (the most promising being those of white mustard), which will be spread by the straw chopper together with straw quite homogeneously on the field) – corn – soybeans. Here, although many variants are possible, most importantly, the proportion of corn in the crop rotation should be at least 25%, wheat or rye with green manure – 25%; promising monoculture of maize up to 15 years old. Under such conditions, within 3-4 years, a 3-4 cm layer of mulch will be created, which will give reason to speak about the beginning of No-till.

Table 4 presents the energy assessment of the investigated technologies. We propose to take the ratio of plant residues energy to the technological costs energy (fuel, fertilizers) as the standard of technological impact (T_a) on the soil [8]. It was found that for chernozem soils the above index should be at least 8,5 [8]. This means that T_a standard is not maintained even during zero-till, which is additional proof of the crop rotation inadequacy for No-till conditions, and for chernozem in general.

Table 4. Energy assessment of stationary experiment technologies at the Panfil Research Station "NSC Institute of Agriculture of the NAAS", GJ / ha, **2010-2017**

Cultivation	**PR***	**Fuel**	**Fertilizers**	**Fuel+ fertilizers**	**PR/Fuel+ fertilizers**
Plowing without fertilizers	72,3	1,6	0	1,6	45,2
Plowing with fertilizers	80,2	1,6	11,1	12,7	6,3

No-till without fertilizers	71,5	0,4	0	0,4	178,8
No-till with fertilizers	83,2	0,4	11,1	11,5	7,2

*PR - energy of plant residues; Fuel - fuel energy; Fertilizers - energy of fertilizers

The rationing of technological load is a major and urgent problem, whose solution requires in-depth research by teams beyond a single research institute of the National Academy of Agricultural Sciences of Ukraine; therefore, we have shown a fragment of the energy assessment only in the context of the current work.

The analysis of harvest data for 2 sets of 4-crop rotations, as expected, did not reveal significant differences between variants. The zero-till does not give the agronomist the benefits of No-till, where almost all soil regimes determining its fertility are optimized.

Table 5. Crop yields of 4-crop rotations for 2 rotations

Crop	Tillage	Fertilizers	2010	2011	2012	2013	2014	2015	2016	2017	Average
Soybean	No-till	$N_{30}P_{60}K_{65}$	1,87	2,90	3,08	2,98	2,16	2,97	3,0	-	2,71
	No-till	No fertilizer	1,42	2,93	2,42	2,10	1,52	1,85	2,10	1,35	1,96
	Plowing at 25-27 cm	$N_{30}P_{60}K_{65}$	1,99	2,61	3,30	3,25	2,49	3,13	3,24	2,09	2,76
	Plowing at 25-27 cm	No fertilizer	1,70	2,51	3,08	2,28	1,78	2,20	1,98	1,56	2,14
Spring barley	No-till	$N_{100}P_{45}K_{80}$	2,77	3,00	4,30	3,86	4,11	4,85	5,20	3,73	4,00
	No-till	No fertilizer	1,73	2,48	3,52	3,10	3,06	3,36	3,70	2,58	2.94
	Plowing at 20-22 cm	$N_{100}P_{45}K_{80}$	2,03	3.26	5,24	3,79	4,27	4,57	4,15	4,27	3,95
	Plowing at 20-22 cm	No fertilizer	1,88	2,45	4,28	3,33	3,26	3,03	4,99	2,99	3,28
Sunflower	No-till	$N_{150}P_{110}K_{180}$	2,00	4,26	4,09	3,94	3,75	4,05	3,08	1,29	3,31
	No-till	No fertilizer	2,01	3,69	3,15	3,12	2,89	2,50	2,58	0,86	2,60
	Plowing at 25-27 cm	$N_{150}P_{110}K_{180}$	1,68	4,34	4,02	4,12	4,18	3,24	3,02	2,74	3,42
	Plowing at 25-27 cm	No fertilizer	1,64	3,06	3,45	3,06	3,34	2,18	2,42	1,66	2,60
Winter wheat	No-till	$N_{120}P_{90}K_{100}$	2,75	2,93	7,12	5,56	7,06	6,93	5,55	4,99	5,11
	No-till	No fertilizer	-	2,74	5,82	5,06	4,97	5,89	3,25	3,71	4,49
	10-12 cm	$N_{120}P_{90}K_{100}$	2,01	2,54	6,61	5,36	6,79	6,32	3,67	3,59	4,61
	10-12 cm	No fertilizer	1,93	2,55	5,64	5,21	4,82	5,22	5,95	2,99	4,29

Conclusion

- No-till starts from the moment when a 3-4 cm layer of mulch forms on the surface of the soil, subject to 100% coverage;
- the so-called transitional period in the form of no-till should be as short as possible;
- within 10 years of no-till on light loam chernozem, deep agro-physical degradation is observed in the form of reduced micro-aggregation;
- no significant advantages of no-till in increasing crop yields have been observed.

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